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**PLANNING BOARD
GRAFTON, MA**

RF Report

Proposed Wireless Facility
30 Grafton Common
Grafton, MA 01519

verizon✓

March 17, 2017

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1. Overview

This RF Report has been prepared on behalf of Verizon Wireless in support of its application to the Town of Grafton for the installation and operation of a wireless facility located at 30 Grafton Common in Grafton, MA. The proposed facility consists of antennas concealed within the existing church steeple and ground based equipment cabinets.

This report concludes that the proposed site is needed to fill in coverage gaps and provide capacity relief to central sections of Grafton in order to improve deficient service areas along Brigham Hill Road, Millbury Street, North Street, Providence Road, Worcester Street, Upton Street, South Street, and the surrounding roads, neighborhoods, businesses, and community areas with the proximity of the proposed site.

Included in this report is: a brief summary of the site's objectives, maps showing Verizon Wireless' current network plan, and the predicted Radio Frequency coverage of the subject site and the surrounding sites in Verizon Wireless' network.

2. Introduction

Verizon Wireless provides digital voice and data communications services using 3rd Generation (3G) CDMA/EVDO technology in the Cellular (800 MHz) and PCS (1900 MHz) frequency bands, and is in the midst of deploying advanced 4th Generation (4G) voice and data services over LTE technology in the 700 MHz, PCS, and AWS (2100 MHz) frequency bands as allocated by the FCC. These networks are used by mobile devices for fast web browsing, media streaming, and other applications that require broadband connections. The mobile devices that benefit from these advanced networks are not limited to basic handheld phones, but also include devices such as smartphones, PDA's, tablets, and laptop air-cards. With the evolving rollout of 4G LTE services and devices, Verizon Wireless customers will have even faster connections to people, information, and entertainment.

As explained within this report, Verizon Wireless has identified the need to add a new facility to its existing network of sites in the Grafton area to improve capacity and coverage to a significant gap in service that now exists in central Grafton, in order to support reliable communications and meet the growing demand in the area.

To maintain a reliable and robust communications system for the individuals, businesses, public safety workers and others who use its network, Verizon Wireless deploys a network of cell sites (also called wireless communications facilities) throughout the areas in which it is licensed to provide service. These cell sites consist of antennas mounted on structures, such as buildings and towers, supported by radio and power equipment. The receivers and transmitters at each of these sites process signals within a limited geographic area known as a "cell."

Mobile subscriber handsets and wireless devices operate by transmitting and receiving low power radio frequency signals to and from these cell sites. Handset signals that reach the cell site are transferred through land lines (or other means of backhaul transport) and routed to their destinations by sophisticated electronic equipment. In order for Verizon Wireless' network to function effectively, there must be adequate overlapping coverage between the "serving cell" and adjoining cells. This not only allows a user to access the network initially, but also allows for the transfer or "hand-off" of calls and data transmissions from one cell to another, and prevents unintended disconnections or "dropped calls."

Verizon Wireless' antennas also must be located high enough above ground level to allow transmission (a.k.a. propagation) of the radio frequency signals above trees, buildings and other natural or man-made structures that may obstruct or diminish the signals. Areas without adequate radio frequency coverage have substandard service, characterized by dropped and blocked calls, slow data connections, or no wireless service at all, and are commonly referred to as coverage gaps.

The size of the area potentially served by each cell site depends on several factors including the number of antennas used, the height at which the antennas are deployed, the topography of the surrounding land, vegetative cover, and natural or man-made obstructions in the area. The actual service area at any given time also depends on the number of customers who are on the network in range of that cell site. As customers move throughout the service area, the transmission from the phone or other device is automatically transferred to the Verizon Wireless facility with the best reception, without interruption in service, provided that there is overlapping coverage between the cells.

Each cell site must be primarily designed to strike a balance between the overall geographic coverage area it will serve, and the site's capacity to support the usage within the coverage footprint. In rural areas, cell sites are generally designed to have broader coverage footprints because the potential traffic is sparser and distributed over a larger area. In more densely populated suburban and urban environments, the capacity to handle calls and data transmissions is of increasing concern, and cell sites must limit their coverage footprint to an area where the offered network traffic can be supported by the radio equipment and resources. Due to the aggressive historical and projected growth of mobile usage, particularly for mobile data (42% in 2016-2017, 35% CAGR 2016-2021 in North America)¹, instances arise where the usage demand can no longer be supported by the site(s) serving an area, and new facilities must be integrated to provide capacity relief to the overloaded sites.

We have concluded that by installing the proposed wireless communication facility at 30 Grafton Common at an antenna centerline height of 70.1' AGL (above ground level), Verizon Wireless will be able to substantially fill the gap in service that it now experiences, and provide improved coverage and capacity to residents, businesses, and traffic corridors within sections of central Grafton that are currently located within deficient service areas of Verizon Wireless' network.

¹ "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016-2021", February 7, 2017, Cisco Systems, Inc. <http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.html>

3. The Proposed Facility

As shown on the plans submitted with the application, Verizon Wireless' proposal consists principally of the following elements:

- 1) A 12'-0" x 17'-6" concrete equipment pad and protective weather canopy, with telecommunication equipment cabinets, a natural gas back-up power generator, and utility connections, all located at ground level west of the building, and surrounded by an 8' tall wooden stockade fence;
- 2) Six (6) panel antennas at an antenna centerline height of 70.1' AGL, mounted within the existing church steeple behind replacement fiberglass louvers;
- 3) Remote Radio Heads (RRH) with accessory junction boxes and surge suppressors mounted alongside the antennas;
- 4) Power and fiber cables routed underground between the equipment cabinets and the building, up to the proposed RRHs within the steeple.

4. Coverage and Capacity Objectives

As mentioned above, Verizon Wireless is in the process of rolling out its 4G LTE high-speed wireless broadband system in the 700 MHz, PCS, and AWS frequency bands, in accordance with its licenses from the FCC. In order to expand and enhance their wireless services throughout New England, Verizon Wireless must fill in existing coverage gaps and address capacity, interference, and high-speed broadband issues. As part of this effort, Verizon Wireless has determined that insufficient network capacity and significant coverage gaps exist in and around sections of the Town of Grafton, MA, as described further below.

Verizon Wireless currently operates wireless facilities, similar to the proposed facility, within the surrounding cities/towns in the vicinity. Due in large part to the distances between the existing sites, the intervening topography, and volume of user traffic in the area, these existing facilities do not provide sufficient coverage and capacity to portions of Grafton. Specifically, Verizon Wireless determined that much of central Grafton is without reliable service in the following areas and town roads², including but not limited to:

- Brigham Hill Road, east of Kelly Place;
 - Serves 2,200 vehicles per day, as measured west of Route 122 (2002) and,
 - the Grafton High School and Municipal Center
- Millbury Street, east of Crosby Road;
 - Serves 4,651 vehicles per day, as measured west of Route 122 (2011);
- North Street, south of Old Westboro Road;
 - Serves 4,858 vehicles per day, as measured north of Route 140 (2015);
- Providence Road (Route 122), between Worcester Road and Pullard Road;
 - Serves 15,114 vehicles per day, as measured south of Worcester Street (2015);
- Worcester Street (Route 140), south of Forest Lane;
 - Serves 9,654 vehicles per day, as measured south of Oak Street (2016);
- Upton Street (Route 140), west of Meadowbrook Road;
 - Serves 9,099 vehicles per day, as measured east of South Street (2016);
- South Street;
 - Serves 8,700 vehicles per day, as measured east of Worcester Street (2001);
- The surrounding roads, neighborhoods, businesses, and community areas with the proximity of the proposed site.

The proposed site located at 30 Grafton Common ("Grafton 4") is needed to fill in these targeted capacity and coverage gaps, in order to improve network quality and reliability for Verizon Wireless subscribers traveling along these roads, as well as to the numerous residences, businesses, and visitors in this area.

² Traffic counts are sourced from the Massachusetts Department of Transportation, Transportation Data Management System.

5. Site Search and Selection Process

To find a site that provides acceptable service, provides adequate capacity relief, and fills the gaps in coverage, computer modeling software is used to define a search area. The search ring identifies the area within which a site could be located (assuming that sufficient height is used) that would have a high probability of addressing the significant coverage gap and meeting the capacity objectives established by the Verizon Wireless RF (Radio Frequency) engineers.

Once a search ring is determined, Verizon Wireless' real estate specialists search within the proximity of the defined area for existing buildings, towers, and other structures of sufficient height that would meet the defined objectives. If none are found, then the focus shifts to "raw land" sites. A suitable site must satisfy the technical requirements identified by the RF engineers, must be available for lease, and must have access to a road and be otherwise suitable for constructing a cell site of the required size and height. Every effort is made to use existing structures before pursuing a "raw land" build to minimize the number of towers throughout the towns being serviced.

After the search of the area had been completed, Verizon Wireless determined that utilization of the existing church steeple located at 30 Grafton Common is the best solution to address the targeted capacity and coverage objectives with respect to its network requirements.

6. Pertinent Site Data

Table 1 below details the site-specific information for the existing, approved, planned, and proposed Verizon Wireless sites used to perform the coverage analysis and generate the coverage plots provided herein.

Site Name	Address	City/State	Location		Structure Type	Antenna Height (ft AGL)	Status
			Latitude	Longitude			
Auburn 3	198 Washington Street	Auburn, MA	42.2027	-71.8163	Monopole	98	On-Air
Auburn 4	404 Washington Street	Auburn, MA	42.1951	-71.8252	Monopole	90	On-Air
Grafton	20 Indian Path	Grafton, MA	42.2286	-71.6900	Monopole	83	On-Air
Grafton 2	160R Upton Street	Grafton, MA	42.2010	-71.6609	Monopole	88	On-Air
Grafton 3	104 Creeper Hill Road	Grafton, MA	42.2385	-71.7286	Monopole	120	Approved
Grafton 5	58 Follette Street	Grafton, MA	42.1838	-71.7195	Monopole	165	Planned
Grafton East	43 Estabrook Avenue	Grafton, MA	42.2265	-71.6644	Monopole	70	On-Air
Grafton North	200 Westboro Road	Grafton, MA	42.2446	-71.6779	Stealth Pole	87	On-Air
Millbury Center	95 Providence Turnpike	Millbury, MA	42.1941	-71.7702	Stealth Pole	145	On-Air
Northbridge	Mahoney Lane	Northbridge, MA	42.1648	-71.6587	Lattice	177	On-Air
Sutton South	496 Purgatory Road	Northbridge, MA	42.1288	-71.6992	Lattice	160	On-Air
Shrewsbury	161 Memorial Drive	Shrewsbury, MA	42.2585	-71.7081	Lattice	151	On-Air
Shrewsbury 3	508 Boston Turnpike	Shrewsbury, MA	42.2754	-71.7175	Monopole	120	On-Air
Shrewsbury East	800 Boston Turnpike	Shrewsbury, MA	42.2765	-71.6903	Monopole	56	On-Air
Sutton	Kamaitis Road	Sutton, MA	42.1661	-71.7485	Monopole	138	On-Air
Sutton East	194 Stone School Road	Sutton, MA	42.1438	-71.7114	Monopole	118	On-Air
Upton	Off Warren Street	Upton, MA	42.1794	-71.6149	Monopole	130	On-Air
Upton N	87 Adams Street	Upton, MA	42.2279	-71.6313	Monopole	146	On-Air
Westboro 5	15 Spring Road	Westborough, MA	42.2392	-71.5975	Monopine	86	Approved
Westborough S	4 Isaac Miller Road	Westborough, MA	42.2398	-71.6284	Lattice	97	On-Air
Worcester 4	128 Providence Street	Worcester, MA	42.2483	-71.7932	Rooftop	55	On-Air
Worcester 5	21 Heywood Street	Worcester, MA	42.2485	-71.7893	Rooftop	72	On-Air
Worcester E	39 Jolma Road	Worcester, MA	42.2473	-71.7556	Monopole	153	On-Air
Worcester S	442 SW Cut-off	Worcester, MA	42.2218	-71.7740	Lattice	180	On-Air
Grafton 4	30 Grafton Common	Grafton, MA	42.2059	-71.6861	Steeple	70.1	Proposed

Table 1: Verizon Wireless Site Information Used in Coverage Analysis³

³ Some sites listed in this table are outside the plot view but are included for completeness of information.

7. Coverage Analysis and Propagation Plots

The signal propagation plots provided in this report show coverage for the 700 MHz frequency range and were produced using deciBel Planner™, a Windows-based RF propagation computer modeling program and network planning tool. The software takes into account the geographical features of an area, land cover, antenna models, antenna heights, RF transmitting power and receiver thresholds to predict coverage and other related RF parameters used in site design and network expansion.

The plots included as attachments show coverage based on RSRP signal strengths of -90 dBm and -95 dBm. All other areas (depicted in white) fall within coverage areas characterized by poor service quality, low data throughput, and the substantial likelihood of unreliable service.

Attachments A - G are discussed below:

Attachment A titled “Grafton 4 – Existing/Approved 700 MHz LTE Coverage” shows the existing coverage provided to areas of Grafton from the “On-Air” and “Approved” sites listed in Table 1. “On-Air” sites are existing Verizon Wireless facilities, and “Approved” sites are defined as those that are in the final stages of permitting or construction and are expected to be turned on-air in the near future. The green areas represent the minimum desired level of coverage for this area, whereas the orange areas represent a slightly lower signal strength. The deficient areas of coverage are defined by the unshaded or “white” areas. As shown in this plot and described in the Coverage and Capacity Objectives section of this report, much of central Grafton is in an area of deficient coverage. These coverage gaps include Brigham Hill Road, Millbury Street, North Street, Providence Road, Worcester Street, Upton Street, South Street, and the surrounding roads, neighborhoods, businesses, and community areas with the proximity of the proposed site.

Attachment B titled “Grafton 4 – Existing/Approved/Planned 700 MHz LTE Coverage” shows the coverage depicted in **Attachment A**, along with the coverage provided by the “Planned” “Grafton 5” site, which is located approximately 2.3 miles away in southwestern Grafton. “Planned” sites are those which have either started or are expected to begin the permitting process. As shown in this plot, even with the addition of this “Planned” site, the surrounding network of Verizon Wireless sites are unable to provide reliable service to the targeted areas of central Grafton, as described in the Coverage and Capacity Objectives section of this report.

Attachment C titled “Grafton 4 - 700 MHz LTE Coverage with Proposed Site” shows the composite coverage with the proposed “Grafton 4” facility. As shown by the additional areas of coverage, the proposed facility will provide coverage to:

- ~ 0.9 mi along Brigham Hill Road;
- ~ 0.8 mi along Millbury Street;
- ~ 0.7 mi along North Street;
- ~ 0.6 mi along Crosby Road;
- ~ 0.5 mi along Providence Road (Route 122);
- ~ 0.5 mi along Worcester Street (Route 140);
- ~ 0.5 mi along Hudson Avenue;
- ~ 0.5 mi along Oak Street;
- ~ 0.5 mi along Upton Street (Route 140);

- ~ 0.3 mi along South Street;
- ~ 1,480 new residents⁴ within the proximity of the proposed facility;
- The surrounding roads, neighborhoods, businesses, and community areas with the proximity of the proposed site, including but not limited to:
 - The Grafton Fire Department, Public Library, the Grafton Municipal Center and the Grafton High School.

Attachment D titled “Grafton 4 – Existing/Approved 700 MHz LTE Sector Footprints” depicts the areas primarily served by the sectors (a.k.a. signal “footprints”) of the “On-Air” and “Approved” Verizon Wireless sites in the area, which shows a unique color for each particular sector of interest. For clarity, all other sectors of less interest with respect to the proposed site are shown in grey. As demand for wireless voice and data services continues to grow, Verizon Wireless manages the footprint of each sector so that it can support the demand within the area it is primarily serving. In addition to improving coverage to the area, the proposed site is also needed to serve existing and anticipated demand in the vicinity and thereby offload some of the burden experienced by the surrounding sites. In that way, those sites will be able to more adequately serve the demand for service in the areas nearer to those surrounding sites. Please note that the outer parts of each sector footprint include areas that presently have signal strength below the targeted value required for reliable service to Verizon Wireless’ customers. The fact that low-level signal is capable of reaching these areas does not mean that these areas experience adequate coverage. These unreliable areas of low signal level impose a significant capacity burden on the sites primarily serving the area.

Attachment E titled “Grafton 4 – Existing/Approved/Planned 700 MHz LTE Sector Footprints” depicts the areas primarily served by the sectors (a.k.a. signal “footprints”) shown in **Attachment D**, along with the “Planned” “Grafton 5” site. While this “Planned” site is capable of providing low-level signal to the targeted area of central Grafton, as mentioned above, the fact that low-level signal is capable of reaching this area does not mean that there is adequate coverage. Inadequate coverage on the outer fringes of a site’s footprint further impacts the overall capacity burden and service deficiency on a sector.

Attachment F titled “Grafton 4 - 700 MHz LTE Sector Footprints with Proposed Site” shows the composite coverage with the overall footprint of the proposed facility in dark green. As shown in this map, the proposed “Grafton 4” facility is an effective solution to provide the necessary capacity relief to the area, particularly to the “Grafton” beta (orange) and gamma (red) sectors, and the “Sutton” alpha (yellow) sector. The proposed facility is centrally located in the area of deficient coverage making it particularly suited to distribute the traffic load across multiple sectors, and provide a dominant server to this pocket of heavy usage. Table 2 below details the capacity relief based on the sector footprints shown in Attachments D and F. Please note that the capacity offload statistics reflected in Table 2 below represents the expected offload from both the planned Grafton 5 and proposed Grafton 4 sites.

⁴ Residential population counts are based upon the 2010 U.S. Census data. Please note that this does not include employee, visitor, or vehicular counts in the area.

Sector	Current		With "Grafton 4" and "Grafton 5"		Offload Summary	
	Residential Pops	Area (mi ²)	Residential Pops	Area (mi ²)	Total Residential Pops Offloaded	Area Offloaded (mi ² /%)
Grafton Beta	414	1.04	335	0.91	79 (19.1%)	0.13 (12.5%)
Grafton Gamma	2921	2.75	1464	1.29	1457 (49.9%)	1.46 (53.1%)
Sutton Alpha	5686	6.08	1464	1.87	4222 (74.3%)	4.21 (69.2%)

Table 2: Capacity Offload Summary⁵

Attachment G titled "Grafton 4 – Area Terrain Map" details the terrain features around the proposed "Grafton 4" site. These terrain features play a key role in dictating both the unique coverage areas served from a given location, and the coverage gaps within the network. This map is included to provide a visual representation of the terrain variations that must be considered when determining the appropriate location and design of a proposed wireless facility. The darker blue and green shades correspond to lower elevations, whereas the lighter yellow, red, and grey shades indicate higher elevations.

8. Certification of Non-Interference

Verizon Wireless certifies that the proposed facility will not cause interference to any lawfully operating emergency communication system, television, telephone or radio, in the surrounding area. The FCC has licensed Verizon Wireless to transmit and receive in the Upper C-Block of the 700 MHz band, B Block of the Cellular (850 MHz) band, the F and C3 Blocks of the PCS (1900 MHz) band, and the A and B Blocks of the AWS (2100 MHz) band of the RF spectrum. As a condition of the FCC licenses, Verizon Wireless is prohibited from interfering with other licensed devices that are being operated in a lawful manner. Furthermore, no emergency communication system, television, telephone, or radio is licensed to operate on these frequencies, and therefore interference is highly unlikely.

⁵ Residential population counts are based upon the 2010 U.S. Census data. Please note that this does not include employee, visitor, or vehicular counts in the area.

9. Summary

In undertaking its build-out of 4G LTE service in Worcester County, Verizon Wireless has determined that this additional facility is needed to provide reliable service and adequate capacity throughout areas of the Town of Grafton, MA. Verizon Wireless determined that collocating within the existing church steeple at 30 Grafton Common in Grafton will provide additional coverage and capacity needed in the targeted coverage areas including key roadways such as Brigham Hill Road, Millbury Street, North Street, Providence Road, Worcester Street, Upton Street, South Street, and the surrounding roads, neighborhoods, businesses, and community areas with the proximity of the proposed site. Without the installation of the proposed site, Verizon Wireless will be unable to improve and expand their existing 4G LTE wireless communication services in this area of Grafton; therefore, Verizon Wireless respectfully requests that the Town of Grafton act favorably upon the proposed facility.

10. Statement of Certification

I certify to the best of my knowledge that the statements in this report are true and accurate.

Keith Vellante

Keith Vellante
RF Engineer
C Squared Systems, LLC

March 17, 2017

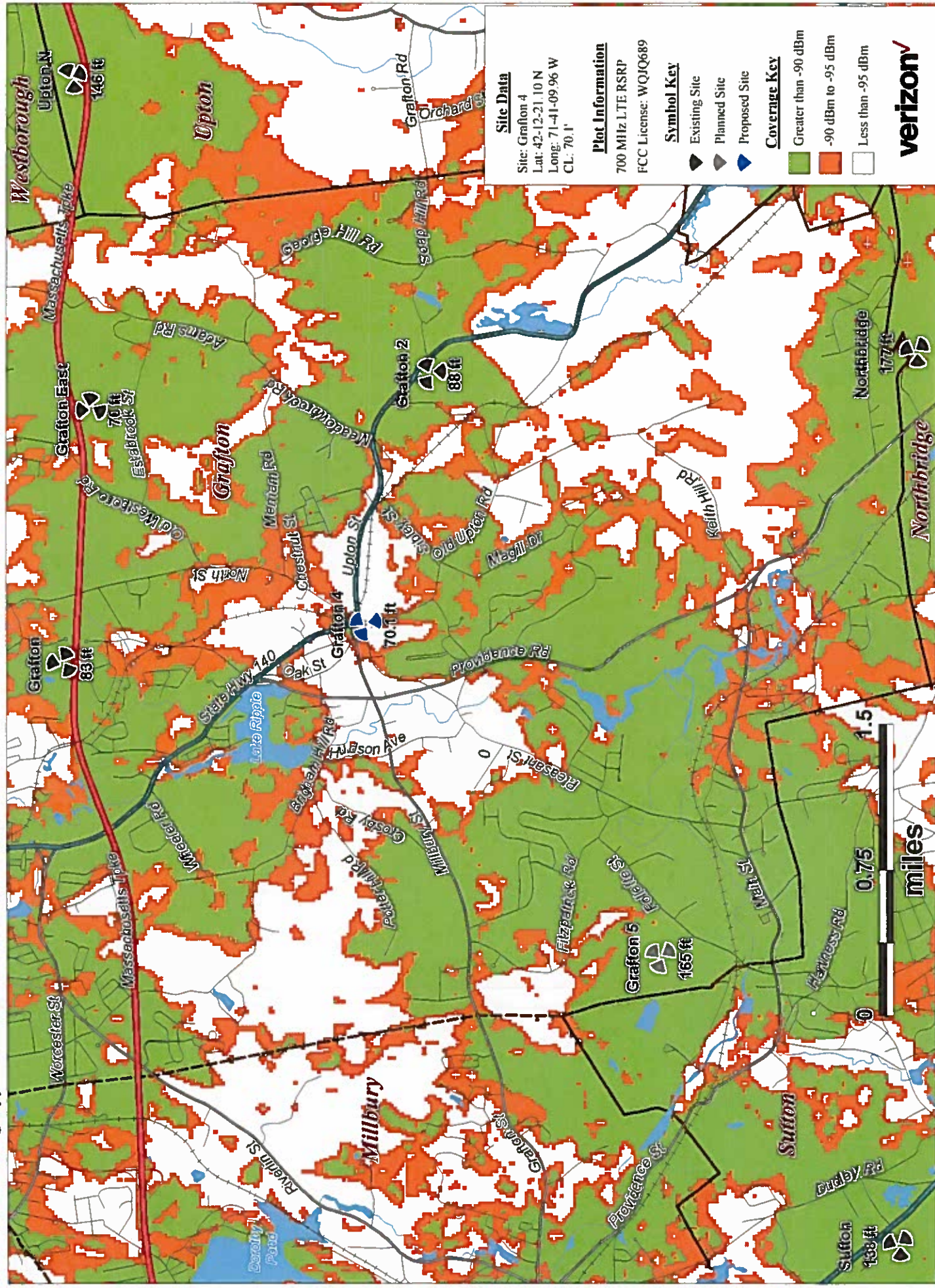
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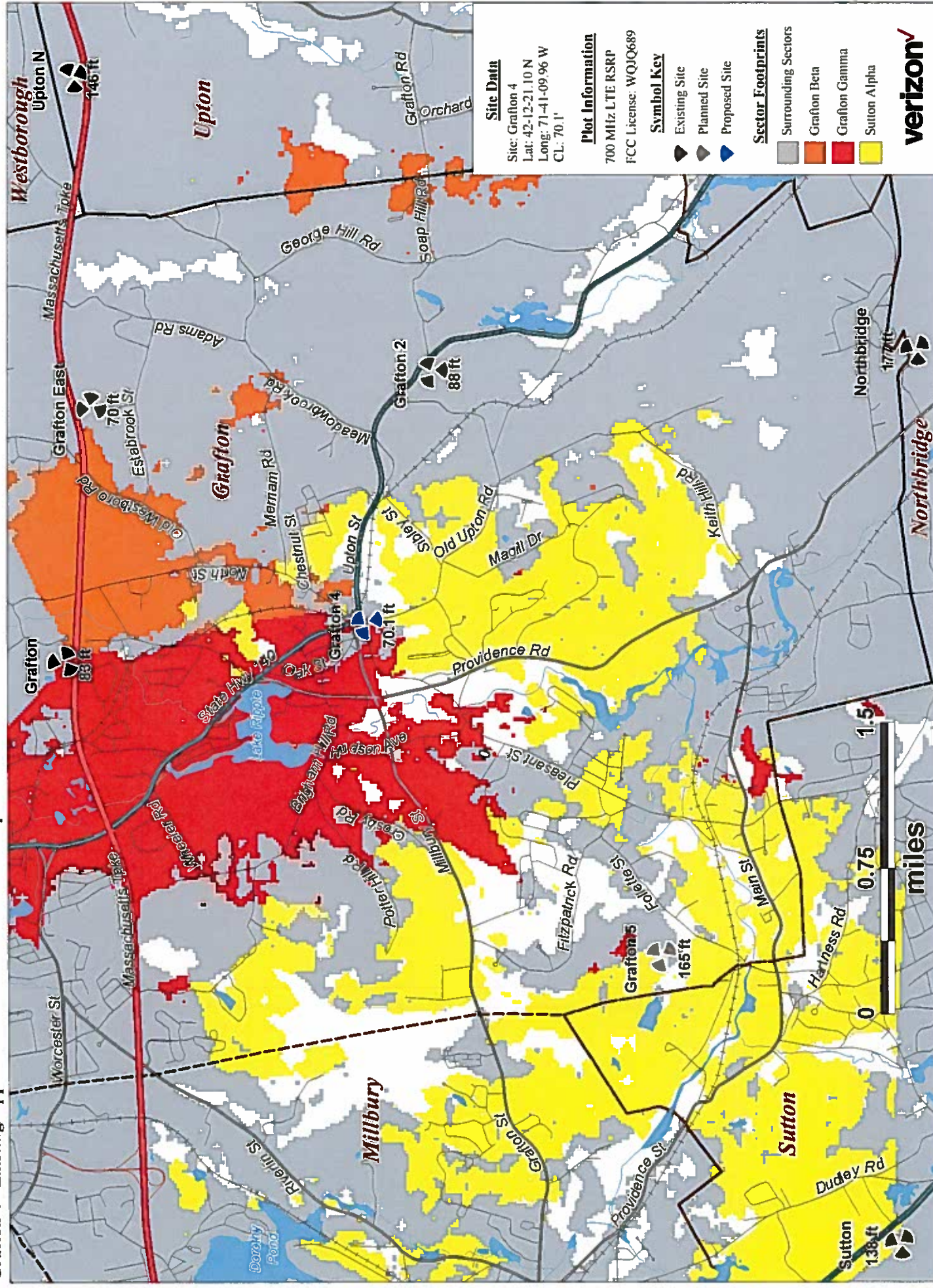
11. Attachments

Attachment A:

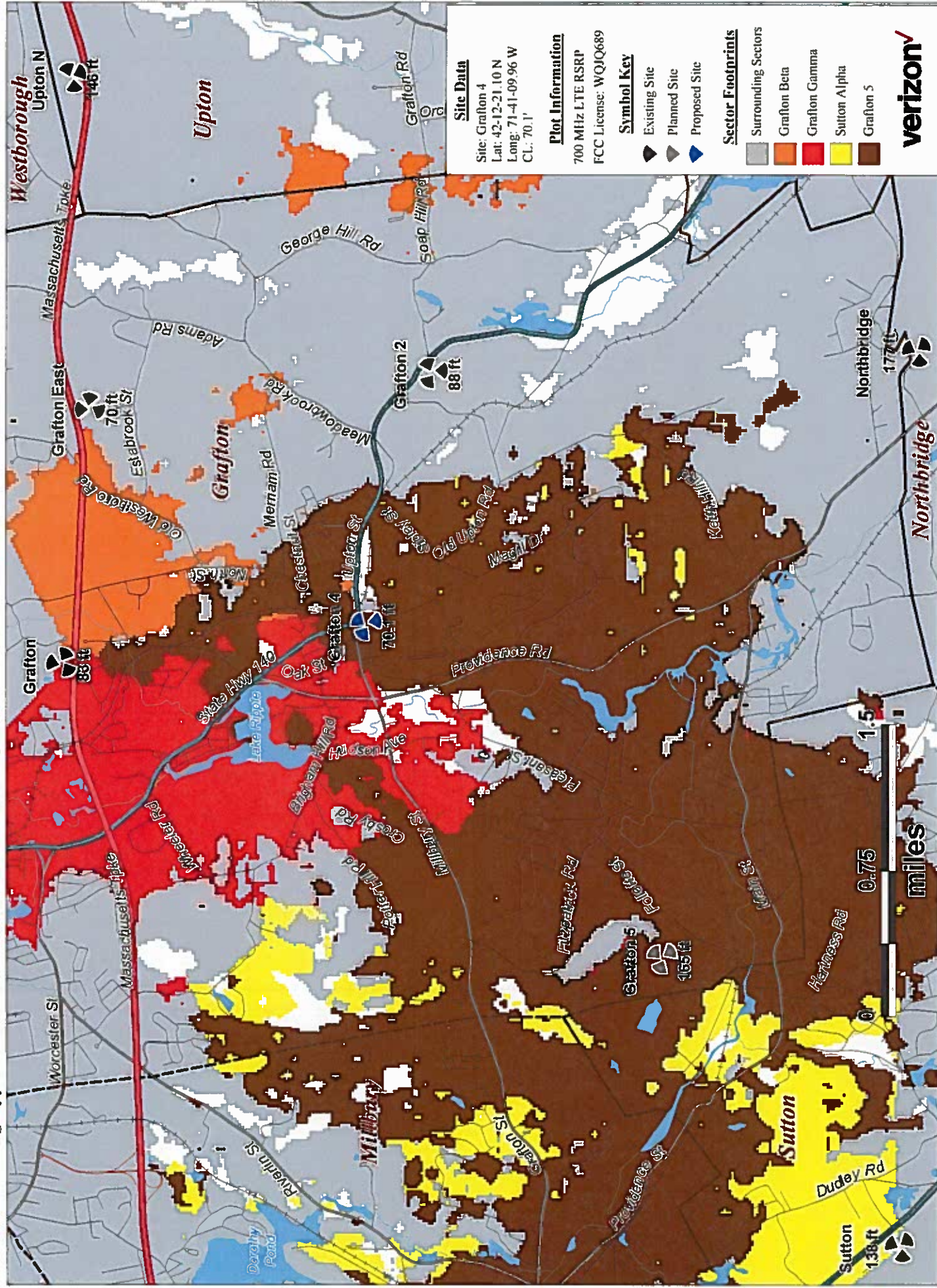


Grafton 4 - Existing/Approved/Planned 700 MHz LTE Coverage



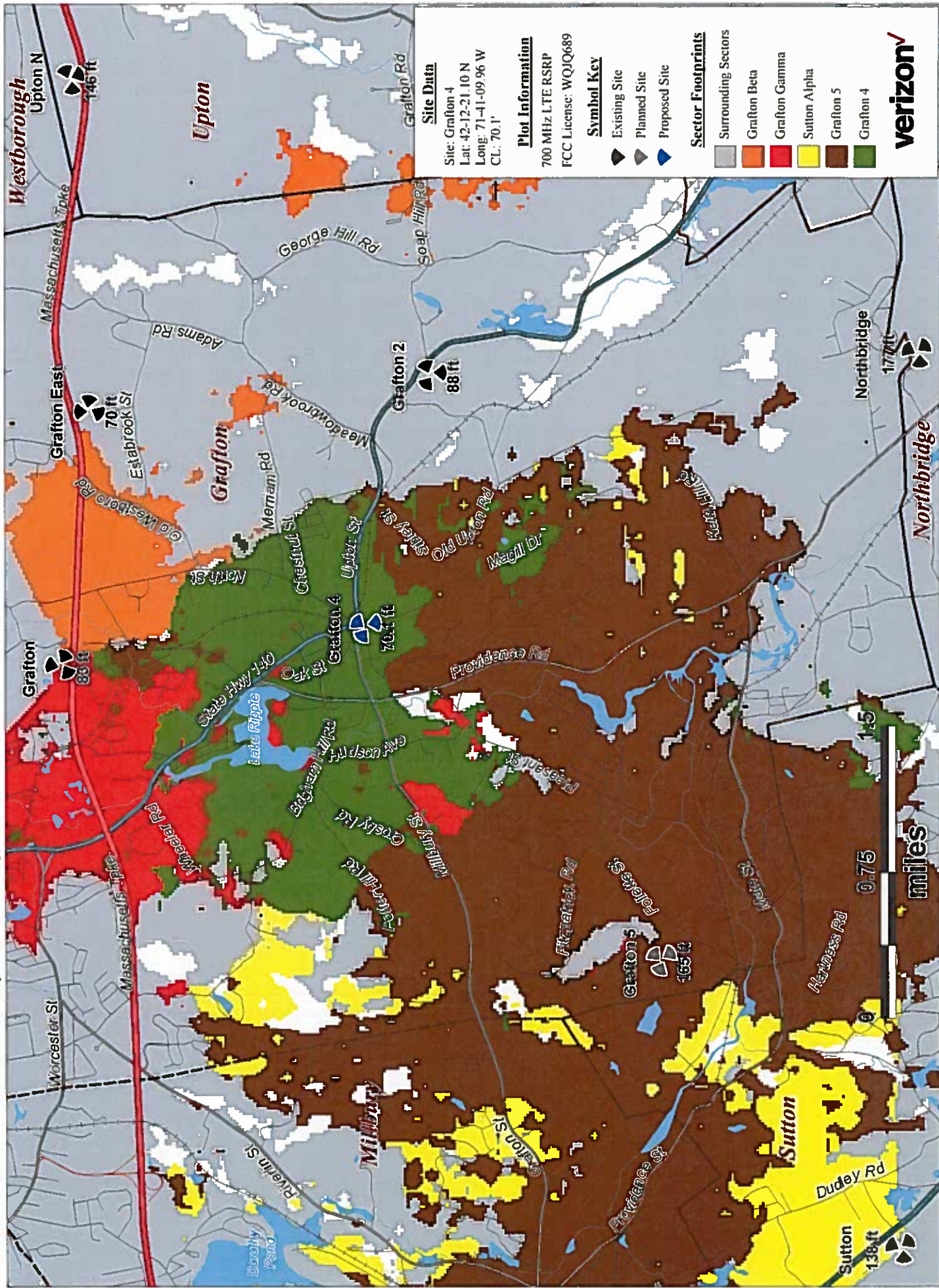


Grafton 4 - Existing/Approved/Planned 700 MHz LTE Sector Footprints



Attachment F:

Grafton 4 - 700 MHz LTE Sector Footprints with Proposed Site



Attachment G:
Grafton 4 - Area Terrain Map

